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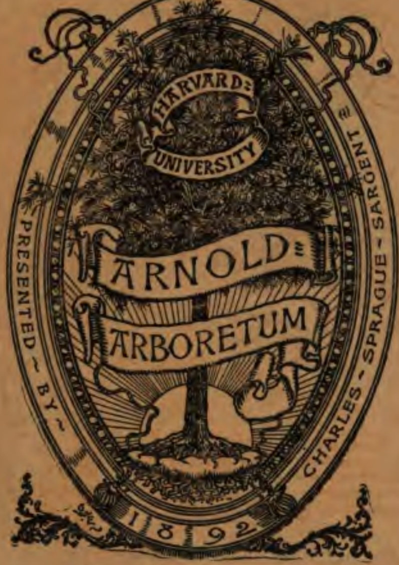

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CONCERNING THE

ENHANCEMENT OF INCREMENT

WHICH TAKES PLACE IN

TREE-FOREST

AFTER

HEAVY THINNINGS OR PARTIAL CLEARANCE

FOR THE PURPOSE OF

PERMITTING THE TIMBER CROP TO HAVE A FULLER ENJOYMENT OF LIGHT, AIR, AND WARMTH.

BY

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CONCERNING THE

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It is a well-known fact that when trees growing in close canopy are thinned out, or when in the case of old crops approaching maturity a partial clearance is made, the annual increment on each individual stem naturally rises in consequence of the decrease in the number of stems drawing food-supplies and moisture from the soil, and engaging in the struggle for light and air.

In the system of selecting only the largest trees for extraction, in standards over coppice, and in standard trees retained in high forest for a second period of rotation, such increment in growth is certainly attained; but in the following the question to be considered is mainly connected with heavy thinnings or partial clearance made shortly before a crop falls to the axe, in order to stimulate the remaining trees to more energetic growth in girth before the date at which the fall must take place according to the working-plan. It is, in fact, but the continuation of the thinnings that have taken place as measures of tending throughout the whole lifetime of the crop, only it is carried out more freely on account of this being the last thinning that is to be made before the crop attains its full maturity. If less than one-fifth of the total amount of timber on the area be removed the operation may still be considered as a *heavy thinning*, whilst if one-fifth or more of the crop be thus prematurely utilised it must certainly be considered a *partial clearance*.

That such measures undoubtedly do lead to a stimulation of the annual increment is a fact not only abundantly shown by practical experience, but also proved more than half a century ago by the more eminent sylviculturists of Germany, C. Heyer, Th. Hartig, Nördlinger, and others. They showed conclusively that a stimulation of the increment on individual stems took place, as the natural result of all such thinnings as exceeded in degree the natural process of that struggle for existence in which the stronger first overtops and finally suppresses the weaker individual stems, whenever such free thinnings were made in forests growing in close canopy, and at an age not exceeding to any considerable extent the normal periods of rotation under which the species of tree in question was usually grown as a timber crop. Every now and again, however, some champion steps forward to dispute what have long been accepted as facts; but the plausible deductions drawn from his observations are always on closer investigation found to have some flaw. Thus, for example, he may have confined his attention to the bole only, or have neglected to discriminate between the direct effects of the freer enjoyment of light and air, and the adventitious circumstances under which the latter may have taken place, these concrete conditions being at times of such influence as to diminish or even counteract the intended results of the thinning or partial clearance.

There is generally some very easily determinable reason when this latter measure fails to produce more energetic increment. The thinning or partial clearance may, for example, have been carried so far as actually to have interfered with the normal functions of the root-systems and crowns of foliage of the individuals left forming the crop. These *nouveaux riches* may often require some little time to settle down and accustom themselves to their altered circumstances; and the first form in which this makes itself apparent is very frequently rather in the energetic formation of new roots and thicker foliage, which ultimately exert their due influence on the increment of the stem, than in the immediate thickening of the annual rings, or the formation of woody-fibrous tissue. And wherever the other main factors exerting influence on the productive capacity of the soil are not at the same time tended and well provided for, stimulated increment cannot always be expected as the natural result of diminishing the number of trees forming the crop. Thus, for example, care must be taken to prevent deterioration of the soil (where necessary by underplanting) in consequence of insolation and of the drying and exhausting effects of winds, or with regard to the soil-moisture and to the soil-covering of dead foliage requisite for the formation of humus or vegetable mould.

In one case, however, the current increment of the trees may be directly decreased at first in place of stimulated, namely, when the fuller enjoyment of light and air leads in the first instance to abnormal increase in the production of seed in consequence of a tendency to the formation of albuminoid substances in place of carbonic hydrates,* as is especially liable to take place in the case of trees that were already predominating throughout the canopy at the time of the partial clearance being made. And, of course, if the partial clearance be carried too far, the increment on the remaining crop is injuriously affected by the natural consequences resulting from over-exposure of the soil to insolation and the action of winds, and from exposure of the stems themselves to sunburn or scorching of the bole in smooth-barked species, to increased danger from windfall and insects, as also to the greater damage apt to be done during the felling of the stems to be removed, and the grubbing up of their stumps.

Theodor Hartig was the first to assert† that, as the direct and immediate consequence of freer enjoyment of light and air, without reference to the species of tree, stimulated increment on each individual tree invariably took place, though subject to the influence of the other factors determining the rate of growth. When any apparent exceptions to this rule take place, they are neither ascribable to differences in the species of trees, nor to differences in respect of soil and situation, but are solely due to one or more of the above-indicated causes. Species of timber, soil, and situation certainly exert their influence as regards the extent to which increment may take place, but are not of themselves the direct or prime cause; there is, however, good reason to believe that deciduous trees are enabled by nature to avail themselves of the direct and immediate increment to a somewhat greater extent than the coniferous trees which retain their foliage throughout the whole year.

The enhanced increment need not assume the form of broader annual zones of woody-fibrous tissue along the bole, but may, and very often does, at first take the shape of considerable changes throughout the root-system and the crown of foliage, primarily and undoubtedly due to the freer enjoyment of light, air, and warmth; this paves the way for the succeeding form of enhanced increment, due to these changes in and increment of the assimilative organs, which makes itself more readily distinguishable throughout the stem and branches.

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* Rinicker, "*Der Zuwachsgang in Fichten-und Buchenbeständen,*" 1886, page 30.

† "*Lehrbuch für Förster,*" 1861, Vol. I., page 105.

The extent to which the annual increment thus becomes enhanced varies in any particular species of tree according to the individual stem, its age and reproductive capacity, the soil, situation, and exposure on which the crop grows, the density of the canopy throughout the crop, and the development of the crown of foliage borne by the individual stem. The younger and sturdier the tree, the better developed its crown, the more favourable soil and situation may be to the thriving of the particular species of tree, and the denser or more crowded the wood, so much the more likely is the influence of the thinning or partial clearance to be readily observable. That the extent to which it is perceptible varies in the different species of our forest trees has been above indicated and really requires no explanation. Thus, for example, oak, pine, and larch that have been grown in pure forests, in which there is a strong tendency for the trees to thin themselves naturally to such an extent as to make the canopy loose, if not broken, and to allow of each individual stem forming a larger crown than is usual in the case of shade-bearing species like beech, spruce, and silver fir, can hardly be expected to derive so much benefit as the latter from an artificial diminution of the number of stems per acre. In many such cases indeed this natural thinning, especially when the oak, larch, and pine are approaching the time of maturity of the crop, may have proceeded so far that any further artificial clearance might lead to diminution instead of enhancement of the increment of the remaining stems in consequence of deterioration of the soil, unless underplanting take place at the same time in order to improve, or at any rate protect, its productive capacity. As it is well expressed by Gayer,* the founder of the modern school of scientific sylviculture,—

> " Whenever the partial clearance is likely to lead to interruption of the canopy of the crop, it should only be carried out when the productive capacity of the soil is such as promises in all its essential factors to supply continuously the increased demands made in consequence of greater energy in the crown of foliage (transpiration and assimilation), *i.e.*, that the soil in question is fertile, or that care may be taken to stimulate the productive capacity of the soil in some suitable way at the proper time. This can only take place through the maintenance of a good layer of humus and the careful retention of soil-moisture, and consequently in many cases only by means of *underplanting* in order to protect the soil against sun and wind."

But in the case of the shade-bearing species, beech, spruce, and silver fir, which (except in cases of accident) remain in dense canopy throughout their whole period of growth, right up till their normal maturity, the effects of the freer enjoyment of light, air, and warmth procured for the individual stems by heavy thinning, or by partial clearance when they approach the prescribed time of fall, are often during the first year marked by a two-fold to ten-fold increase in the breadth of the annual zone of woody-fibrous tissue.* This stimulation of increment can also in the case of these trees be attained with a far less degree of clearance, so that, with proper care, there need be small danger of the soil being in any way injuriously affected owing to the partial and temporary interruption of the canopy to a slight degree, a fact easily explained by the lesser absolute measure of light and air enjoyed by these shade-bearing species when grown in canopy of normal density.

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* " *Waldbau*," 3rd edition, 1889, page 571.

Thus, whilst the laws regulating the increment in all species of forest trees are substantially constant, the extent to which the enhancement of increment takes place after partial clearance has, so far as observations have yet been recorded, been found to be practically in the inverse ratio to the requirements of any particular species in regard to light and freedom of crown.

THE CAUSES OF THE ENHANCED INCREMENT EXPLAINED.

Various causes have been assigned to the effects produced in enhanced increment after partial clearance.† Th. Hartig considered it to be due rather to the utilisation of reserves of productive matter collected and stored up in the stem whilst it stood in close canopy, than to any increased assimilation in direct consequence of the increase in foliage that takes place when the individual tree obtains a larger growing space; whilst Nördlinger, on the other hand, ascribed the enhancement in increment to the increase in the foliage, but laid particular stress upon what he considered the fact, that the enhancement was not so much the direct result of the increase in the mass of foliage as of the stimulated assimilative activity of the leaves and needles, with simultaneous temporary increase in the productive capacity of the soil.

The correct explanation as to the enhanced increment is probably to be found in a combination of these views, for it is much more than probable that the utilisation of the reserves of productive matter (principally starch in various forms) is most likely greatly favoured by the more active assimilation of nutrients whenever the increase in the foliage takes places, and there is no reason why they should not be directly connected with the formation of the fuller crown of foliage immediately after the partial clearance has been made. It is still an open question how such reserves of nutrients are formed, how they circulate throughout the tree, and how they are finally utilised, although their existence in the parenchym-cells of woody-fibrous plants is just as well known as that of similar reserves in orchids, perennial tuberous plants, &c. The recent destruction of forests in Bavaria by the Nun moth has given Professor R. Hartig of Munich special opportunities of studying a part of this subject, particularly in regard to the spruce,* and he has conclusively proved that this species of tree has far less reserve supplies of nutrients than the Scots pine. In general, as is well known, such reserve supplies are far more plentiful in the broad-leaved deciduous species of trees than in conifers, and larger in the deciduous larch than in the evergreen conifers. All the changes that take place in trees prior to the commencement of the assimilative activity in spring are ascribable to these nutrient reserves,—the flowering of hazel, alder, and willow, the swelling of the buds and the flushing of the young leaves, the formation of rootlets; in fact, all the similar phenomena previous to the development of independent cambial activity must be ascribed to these reserve supplies of starchy and nitrogenous nutrients. The supply of reserves is usually sufficient to maintain vegetation for one complete year, and often for longer; indeed in many cases it amounts to 7 or 8 per cent. of the total weight of 30-year-old timber crops. Diminution of light and foliage consequent on limitation of growing-space must interfere with the utilisation of these reserve nutrients, and it is quite logical and reasonable to expect that with more growing-space and a consequent increase of foliage these reserves should be largely drawn upon and utilised.

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* Grasmann, "*Beitrag zur Lehre vom Lichtungszuwachs,*" 1890, page 9.

† Grasmann, *op. cit.*, page 4.

That any stimulation of the productive capacity of the soil takes place in consequence of the freer penetration of the atmosphere and the stimulus given to the production of humus or vegetable mould is doubtful, or even more than doubtful, for unless the canopy still remains comparativeiy dense the soil soon becomes covered with forest weeds, which often really consume the mould and tend to exhaust the soil in place of allowing the timber crop to have the full benefit of the humus.

The true physiological cause of the enhancement in increment after heavy thinnings or partial clearance of crops of trees approaching maturity is to be found in the stimulus to the formation of starchy matter afforded by insolation, the degree of activity of the assimilative organs being dependent on the purity or brilliancy of the rays of light, as the decomposition of the carbonic acid in the atmosphere can only take place when the waves of light attain a certain length. Whilst a crop is growing in full canopy the assimilative activity of the foliage forming the lower portion of the crown is extremely small owing to the low quality of the diffused light which is alone available, but when the canopy is opened up to a sufficient extent these portions of the lower foliage, which have been practically inactive, or may perhaps even have been existing on the work done by the upper leaves or needles, reassume their normal assimilative functions and help to enhance the general increment of the tree. And besides this increased assimilative power of the foliage, the consequent increased formation of new leaves and needles is undoubtedly of enormous influence in maintaining and increasing the general enhancement of increment throughout the stem. As remarked by König,* the direct result of the free enjoyment of light and warmth leads to the better and more energetic development of the leading-shoots, the strengthening of twigs, and the formation of twigs from buds that would otherwise most probably have remained dormant.

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* See "*Forstlich-naturwissenschaftliche Zeitschrift*" for January, February, and March 1892.

The enhanced increment continues until the crop once more forms close canopy, but if again stimulated by a repetition of the thinning out or partial clearance this may—if not accompanied by underplanting—be carried on so far as to involve deterioration of the soil to such an extent that the beneficial influence of light and warmth on the crown is cancelled by the diminished activity of the root-system, involving consequently decreased supplies of moisture and of mineral nutrients for conveyance to the assimilative organs.

The simultaneous underplanting of crops subjected to this system of partial clearance, and especially of those of light-demanding species of trees,—oak, ash, maple, larch, and Scots pine,—has an undoubtedly stimulating result in effecting and maintaining the enhancement of increment after partial clearance, and is of particular interest from the financial point of view. The influences exerted by soil and situation and by the age of the crop, exhibit themselves rather with regard to the extent of the enhancement in increment than to its production and continuance; for unless the individual trees are already far past their normal maturity, and already show signs of the loss of energy in growth due to a foreshadowing of the approach of senile decay, such also receive a fillip from admission to larger growing-space and freer enjoyment of light and warmth. When, however, the vital energies of the trees are weakened by age or disease, normal enhancement of increment must not be looked for, the circulation of the sap throughout the stem being already to a greater or less extent interfered with, whilst the root-system is also unfitted to discharge the extra duties it is called upon to perform. Trees that are not very far past the period at which their current annual increment has culminated, as well as such as have not yet attained the culminating point, are, however, unquestionably stimulated to livelier energy, which manifests itself in enhanced increment. But in practice this system of partial clearance for the speedy formation of the more valuable assortments of timber is seldom applicable to very young woods, or to crops that are already much older than the usual periods of rotation. It generally finds proper scope only in mature crops of high forest and in those approaching maturity; and in these cases the age of the crop has little influence on the length of time throughout which the enhancement of increment is maintained, this being determined rather by the length of time which it takes the crop to form close canopy once more. The nature of the development of the crown is, however, of greater importance than the age of the crop, for if the previous thinnings have been neglected, and the canopy has been allowed to remain so dense that the woods are crowded, it often happens that on receiving increased growing-space the trees with their weakly crowns are unable to avail themselves of the advantages thereby offered, and exhibit, as may so often be seen in the case of oaks, a tendency to the development of dormant buds, which leads to "*stag-headedness*" or death of the crown, and malformation of the bole.

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* "*Ueber Lichtungszuwachs, insbesondere der Buche,*" 1886, page 7.

PRACTICAL ADVANTAGES OF THE METHOD OF PARTIAL CLEARANCE.

From the practical sylvicultural and the financial points of view such heavy thinnings or partial clearances should not be made until after the crop in question has completed its chief growth in height.

Along with the other advantages of natural reproduction under parent standards, the rapid increment in timber, as well as in the technical and financial value of the latter, which takes place after partial clearances for the purpose of regeneration, has drawn considerable attention to this method as a system of treatment of woods, even when their artificial reproduction,—as in the case of oak, maple, larch,—may generally be considered more advisable than natural regeneration. The favourable returns received from the gradual clearance of parent standards in the case of natural reproduction of beech, and of silver fir in particular, as well as the financial advantages that accrue ultimately from the partial clearance and underplanting of indifferent crops of oak, larch, and Scots pine when they approach maturity, have to a great extent dispelled the prejudices that existed against the system in the minds of some as being entirely inconsistent with the natural course of things, and have won for it recognition as a method of treatment worthy of adoption wherever circumstances admit of its practice. There seems little doubt that in the near future it will be carried out to a much greater extent than at present, as it combines most of the advantages of standards over coppice with decided sylvicultural and financial advantages of its own. Thus, for example, by means of this method of partial clearance the larger and more valuable assortment of stems can be produced in a shorter time, *i.e.* at a less cost, whilst instead of a high forest of normal density composed of nearly mature trees, with an average annual increment long past their point of culmination and gradually sinking, an equal and often a greater annual increment per acre is attainable after the partial clearance, paying as well, and often better, than if the full crop had been allowed to attain maturity, besides yielding substantial returns from the timber prematurely utilised. When in natural reproduction the gradual clearance of the parent standards is effected, it is in no way inconsistent with what has been above said if, before the formation of the young crop, the average annual increment of the standards is below that of normal high forest reproduced by total clearance and sowing or planting, seeing that from the time the young crop may be considered formed onwards the enhanced increment on the more or less isolated standards is undoubtedly more favourable financially than when total clearance is followed by artificial reproduction.

That portion of the fixed capital which is represented by the growing crop is considerably reduced by means of the partial clearance, and the money thus derived as intermediate returns can be otherwise utilised in order to yield interest for itself, whilst the material left standing increases in the percentage it affords. Thus, if the partial clearance amounts to one-fifth, or one-third, or one-half of the total crop in close canopy, it has been satisfactorily proved by several authorities* that the enhanced increment on the area partially cleared at least equals, and often exceeds, the total previous current annual increment, notwithstanding the diminution in the number of trees thereafter forming the crop.

The financial advantages derivable are thus summarised by Grasmann† :—

(1.) The larger and better-paid assortments of timber can be produced in shorter time, and therefore more cheaply, by this method.

(2.) Instead of the full crop, with small annual increment on a larger number of individual stems, three factors are favourably introduced and combined, viz. :—

(i.) Good intermediate returns are available, capable of producing interest for themselves.

(ii.) The enhanced annual increment on the remaining crop equals, and often exceeds, that produced by the full crop previous to its partial clearance.

(iii.) The naturally or artificially produced young crop under the parent standards often practically equals in increment a young crop formed artificially by sowing or planting.

What Loudon says‡ of the oak may be applied to all our forest trees grown as crops with a view to remunerative returns from the capital invested :—

> " *The age at which oak timber ought to be felled, with a view to profit,* must depend on the soil and climate in which the tree is grown, as well as on other circumstances. Whenever the tree has arrived at that period of its growth, that the annual increase does not amount in value to the marketable interest of the money which, at the time, the tree would produce if cut down, then it would appear more profitable to cut it down than to let it stand."

Whilst this is perfectly correct for each individual tree grown in the comparatively isolated positions that timber trees usually occupied in Britain at the time the above was written, it in no way precludes the possibility, which in fact we know from actual experience to be the case, that when the current annual increment per acre has sunk below the point up to which it is not unprofitable to allow a crop to remain in the full normal canopy of its species, it can be stimulated and rendered more profitable, often very considerably so, by the above-indicated method of partial clearance with a view to the earlier production of valuable stems of large girth. In regular high forest, with natural reproduction, the time of regeneration is often, in order to attain good boles of valuable dimensions, prolonged till after the period when energy for the formation of seed or the natural reproductive capacity is already somewhat weakened. By means of partial clearances, however, the regeneration can be favoured during the chief natural seed-producing period of growth, whilst, at the same time, as good dimensions of timber may be obtainable as in the regular high forest, and in a more profitable manner. Thus, for example, in the reproduction of spruce in sheltered localities, where windfall is not likely to occur, and where the period of reproduction may be taken to be usually about 100 years, if partial clearance be made about the 70th year, during the time of the most active production of seed, the financial position of soil plus crop during the succeeding 30 years will almost, beyond question or doubt, be much more favourable than if the crop had been allowed to stand as regular high forest till the full period of rotation originally fixed in the working-plan had been attained; for it is almost certain that the partially cleared crop will contain a relatively higher number of boles of valuable assortments than would have developed themselves under the system of regular high forest. And what is said here in regard to spruce is still more applicable in regard to the other two great shade-bearing species, the silver fir and the beech. The whole system is in fact merely a modification of and improvement on the old system of natural reproduction under parent standards; but whilst in the latter case the seed fellings (partial clearances) before and during the time of seeding, and the gradual clearances after the formation of the young crop took place mainly with the object of effecting natural regeneration, the partial clearances under the new method are made with the distinctly avowed intention of stimulating the standard crop to enhancement of the annual increment, and to the yield of more favourable returns from the capital represented by soil and growing crop. In the former case formation of a young crop was the motive, and enhanced increment on the parent standards the effect; in the latter, enhancement of annual increment is the object, and simultaneous natural reproduction of shade-bearing species the result of this sylvicultural operation.

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* Wagener, "*Der Waldbau und seine Fortbildung,*" 1884, page 208; Kraft, "*Beitrage zur forstlichen Zuwachsrechnung,*" 1885, pages 99 *et seq.*

† *Op. cit.*, page 11.

‡ "*Arboretum et Fruticetum Britannicum,*" 1838, Vol. III., page 1809.

RULES FOR THE CARRYING-OUT OF PARTIAL CLEARANCES.

With the light-demanding species of trees, when they are not grown in mixed forests along with shade-bearing species, underplanting is almost a necessity after heavy thinnings or partial clearances, in order to maintain the productive capacity of the soil. The manner in which this method of treatment is applied to the various chief species of our light-demanding forest trees—oak, pine, and larch—is as follows:—

Oak.—When pure forests of oak have passed through the regular processes of thinning, and approach the time for partial clearance taking place, their canopy is in general somewhat light and thin, although perhaps not broken, and the undergrowth is usually already beginning to form canopy for itself below the older crop. To avoid the formation of twigs and shoots from the dormant buds along the stem, often leading to "*stag-headedness,*" the partial clearance should not be made by one fall, but is better attained by one or two heavy thinnings conducted to the extent deemed advisable for each individual crop. The time at which it should take place is also dependent on the special circumstances of each crop, but chiefly with regard to the time of underplanting and the development of the undergrowth, the energy of growth of the trees, and the nature of the soil and situation. As, however, the efficacy of this method of treatment is all the more apparent the earlier it can be begun, the thinnings should, if possible, be commenced about the 40th to 60th year, being at first confined to the young stems of backward growth, and to such as are never likely to attain good marketable shape. The oftener the thinnings can be repeated at short intervals the better, as any sudden exposure of the boles should be carefully avoided.

About 10 or 15 years after these preliminary operations have been begun, the main partial clearance will in most cases seem advisable, for by that time the crop should be in a state of active increment, due to the favourable influences of the undergrowth and the previous thinnings. Here, again, as also whenever further partial clearances are considered necessary later on, the fall is in the first instance confined to trees that have been damaged by organic or inorganic agencies, or that do not continue to yield satisfactory increment; and not until all such unremunerative material has been removed should sound trees in energetic growth be cut out.

When the main partial clearance has taken place about the 70th year, and has been followed by minor gradual clearances at intervals of five years at first, then of 10, and later on of 15, the preliminary yield or intermediate returns thus obtained amount according to Kraft,* respectively to about 288 to 628 cubic feet, then to 720 to 1,080 cubic feet, and ultimately to 1,800 cubic feet per acre, inclusive of brushwood. Past experience seems, according to Gayer,† to justify the hope that by this method of treatment the same dimensions of bole can be attained in about 120 years as are obtainable in pure forests worked with a rotation of 200 to 240 years, provided that up till about the 100th year the rate of increment has been maintained at 3 to 3½ per cent., and after that at 2 to 2½ per cent., conditions which are quite conformable with the actual results obtained on suitable soils. The crop of oak then ultimately harvested numbers about 36 to 48 stems per acre, which on good soil yield valuable and well-paid assortments of timber.‡ Where soil and situation are good enough to fulfil the demands made on them, there can be little doubt that this system of underplanting with a shade-bearing species, and partially clearing the main crop from time to time, is the one best calculated to produce timber of highest value for technical purposes, and to yield the most favourable returns financially from the capital represented by the soil, together with the growing crop.

Scots Pine.—For the practice of this method a good deep soil is necessary, as it differs essentially from the custom, common on poorer qualities of soil, of thinning out crops during their 20th to 50th year of age and underplanting them with spruce or other suitable shade-bearing species. In the latter case they are often allowed to grow on to maturity without any further thinning or interruption of the canopy to speak of; but though they continue to improve in growth and form, this is due to the beneficial influence of the undergrowth both on the soil and the standards. As a good formation of the crown is requisite for

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* "*Aus dem Walde,*" Vol. IX., page 80.

† *Op. cit.*, page 574.

‡ The following passage from Loudon's work already quoted (page 1809) is interesting, although not quite intelligible as regards "*the largest scantlings*" being produced at 130 years of age, though if "*larger*" be read in place of "*the largest*" the statement readily becomes intelligible:—

"A writer in the *Gardener's Magazine* states that Mr. Larkin, an eminent purveyor of timber for ship-building, stated, when examined before the East India Shipping Committee, that, in situations the most favourable for ship timber (the Weald of Kent, for example), the most profitable time to cut oak was at 90 years old; as, though the largest scantlings were produced at 130 years' growth, the increase in the 40 additional years did not pay 2 per cent. (*Gard. Mag.*, Vol. XI., p. 690.)"

Scots pine in order to enable it to continue for a long time in active energetic increment, thinnings should be made towards the end of the pole-forest stage of growth, and afterwards repeated whenever there seems any danger of the crowns interfering with each other. Underplanting should also be here carried out as soon as the thinnings have taken place with a view to the formation of good individual crowns. By this means, in place of having a pure forest formed, according to Weise's Yield-Tables,* on soil of average quality at 80 years of age by 317 stems per acre, having a mean average girth of 29 inches at breast-height, which would only be attained by about 40 per cent. or 127 stems, with a form factor of 0·45 and a current annual increment of only 44 cubic feet per acre, it can hardly be doubted that a smaller number of trees with enhanced increment and the finer dimensions of stem effected by the comparatively rapid thickening of the bole at the top end must yield more favourable financial returns on the capital invested in timber production. Reliable comparative data are, however, unfortunately not yet available.

Larch.—In regard to general treatment by partial clearance with a view to the speedy production of large-girthed timber the larch has much in common with the oak; but the underplanting may sometimes take place more advantageously with the silver fir than the beech. So far as experience goes this method of treatment is well adapted to the cultivation of the larch on good, deep soil, and is most satisfactory when the partial clearance and underplanting takes place as early as the 25th to 30th year. When the previous tending of the plantations has been good and the thinnings have been regularly made, the main partial clearance can be heavier than in the case of the oak, so that subsequent clearances are often almost unnecessary. On good soil from 60 to 70 trees per acre remain to form the final yield of the standard crop; and wherever soil and situation are at all suitable for the growth of larch, 60 or 70-year-old crops can often yield an increment of 3 to 4 per cent. up till that age, when they already show good marketable dimensions.

As the beech is not in favour or demand as a timber-tree of large dimensions, this method is only apt to find any practical application with the spruce and the silver fir among shade-bearing species; and as they show many points of similarity, they may be considered together. Where, however, there is any likelihood of windfall or damage from storms, this method is totally unsuited for the spruce.

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* "*Yield-Tables for the Scotch Pine*," translated by W. Schlich, Ph.D., 1888, pages 18 and 19.

Spruce and Silver Fir.—The way for partial clearance should be paved by preliminary operations carried out about the 25th to 30th year in such a manner as to let the predominating poles have a clear space of 2 or 2½ feet around the crowns, these favoured individuals standing about 15 to 17 feet apart, and all the rest of the crop being thinned out in the ordinary manner customary in pure forests without interruption of canopy. During the 30th to 50th year, when the influence of this measure has made itself apparent in the re-formation of close canopy, the main partial clearance takes place in somewhat similar manner, the stems between the favoured individuals being freely thinned so as to permit of the formation of an undergrowth either naturally, or where necessary artificially, wherever the minor portion of the crop is of itself insufficient to protect the productive capacity of the soil. When the favoured stems have at breast-height a girth of about 36 to 40 inches, which they should attain between the 60th to 80th year, the marketable trees can then be gradually cleared away on the same principle.

Another method, practised in the neighbourhood of Salzburg in Western Austria in mixed forests consisting of spruce, silver fir, and beech, consists in carrying out the thinnings once every 10 years after the crop has attained 30 years of age, and making them heavier each time the operation is repeated, until the main partial clearance is made about the 60th or 70th year, leaving 120 to 160 stems per acre, all of them conifers and in energetic growth. Under such a crop natural reproduction can easily be effected, so that about 20 years later the standard trees are of large marketable dimensions, whilst the young growth may vary from 5 to 15 feet in height. On the removal of the standards the blanks thus formed in the new crop can easily be filled up artificially, and may be advantageously utilised for the formation of mixed forests by the introduction of other species.

Actual measurements of crops thus treated are not yet available for comparison with the yield-tables published for pure forests, but the approximate data already given may be contrasted favourably with the more accurate information contained in these latter. According to v. Baur, pure forests of spruce of 120 years in age and growing on good soil have 288 stems per acre, the mean girth of which at breast-height is 39 inches, but this is only attained or exceeded by about 40 per cent. or

115 stems; the mean average stems have also been found to have a form-factor of 0·48, which is undoubtedly lower than that of stems treated by the method of partial clearance. Again, according to Lorey, the silver fir, when grown in pure forest on good soil, yields 200 stems per acre with a mean girth of about 52 inches at breast-height, which also is only attained by about 40 per cent. or 80 stems per acre.

As has already above been pointed out, this method of partial clearance with the distinct object of stimulating the remaining crop to the speedy development of the larger and better-paid assortments of timber cannot be successfully attempted with regard to any species of tree when once its natural energy of growth has practically abated to any considerable extent, or on the poorer classes of soil; but wherever the trees are still capable of stimulation in respect to increment, and the productive capacity of the soil can be easily safeguarded against deterioration, the method has decided practical advantages which should strongly recommend themselves to the woodland proprietors of Britain, where sylvicultural operations on any extensive scale should only be conducted on strictly financial principles.

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